Attachment 1
Retrofit Verification Procedure (Draft)

Technical Review and Verification of Emission Reduction Claims for PM Retrofit Emissions Control Systems for Existing On-Road, Off-Road, and Stationary Diesel-Fueled Engines

1. Emission Control System Information

Emission control systems evaluated in this procedure will be categorized as either:

- Systems expected to reduce PM emissions by at least 85 percent, or to achieve PM levels of 0.01 grams per brake-horsepower-hour (g/bhp-hr) or less[1], or
- Systems expected to achieve reductions primarily in oxides of nitrogen (NOx) emissions, with possible PM emission reductions.

General description: Manufacturers must submit a general description of the emission control system, including a general description of the principles of operation and a schematic depicting operation. Note that systems dependent on two or more individual components must be evaluated as a system (e.g., a catalyst with a particulate filter).

Manufacturers must also identify the emission control system as "active regeneration," "passive regeneration," or "no regeneration needed." An active regeneration system requires an external source outside of normal operation to regenerate the emission control system. Some examples of active regeneration are the use of exhaust fuel injection or the use of heating mechanisms on particulate filters to initiate combustion of collected particulate matter. A passive regeneration system does not require another source other than normal operation to regenerate the emission control system. An example of passive regeneration is a catalyst-coated particulate filter in which the initiation of the regeneration cycle depends on the exhaust temperature.

If an emission control system requires regeneration, the regeneration process may give rise to compatibility issues with the engine or application. Thus, the manufacturer must provide information about the regeneration requirements of the emission control system. This information includes, but is not limited to:

- General description of the regeneration method

[1] For certain engines in specific applications, PM reductions of 85 percent or PM emissions of 0.01 g/bhp-hr or less cannot be claimed because these engines require high exhaust temperatures to operate effectively. In certain applications, manufacturers must demonstrate the highest control emission control systems that require high exhaust temperatures to operate effectively. In certain applications, PM reductions compared to applications with higher less frequently (or not at all), producing lower PM reductions compared to applications with higher

- Favorable and unfavorable operating conditions
- Effects on engine performance and fuel consumption
- Performance data that are monitored
- Thresholds and control logic that are integrated into the system to activate the regeneration process
- Whether the control logic varies from engine to engine and/or application to application

Similar information should be included for non-regenerative systems where applicable. Catalyst-based systems, for instance, have different catalyst formulations depending upon various engine attributes and engine applications. The manufacturer must identify engine and application uses for each catalyst formulation. Other systems, such as selective catalytic reduction, require an additional supply of reducing reagent to assist the emission reduction process. The manufacturer should indicate the consumption rates of the reagent and intervals at which the supply will need to be replenished. Consumption should be based on the engine and/or application.

Fuel requirements: The manufacturer must identify any fuel requirements for proper functioning of the emission control system. For example, an emission control system may be sensitive to sulfur content or may require certain additives for peak performance. The manufacturer must also identify any expected consequences due to misfueling, as well as methods for reversing any negative effects.

Operating conditions: The manufacturer must identify favorable and unfavorable operating conditions for the emission control system, including the effects on the performance of the emission control system and engine.

Maintenance requirements: The manufacturer must identify all normal emission control system maintenance requirements. Examples of maintenance requirements include:

- Specifying the recommended intervals for cleaning and/or replacing components of the emission control system, e.g., filter medium, fuel-borne catalyst. For an emission control system that incorporates “passive” performance monitors, the recommended intervals for checking monitored levels should be identified. For an emission control system that incorporates “active” performance monitors, the maintenance indicator (e.g., malfunction indicator light) should be identified and described.
- Specifying the procedures for cleaning and /or replacing components of the emission control system. This should include procedures for proper handling and disposal of spent components and/or materials cleaned from the filter medium. Procedures for resetting any monitors after maintenance procedures are completed should also be included.

Additional Information: Manufacturers must provide additional information as necessary to demonstrate system compatibility. For example, manufacturers may be required to submit additional data on engine oil consumption and ash content.

2. Emission Testing

Engine selection: The emission control system should be tested on an engine family basis (as described in the Code of Federal Regulations 40 Part 86). The manufacturer must identify the specific engine family and applications (e.g., engine make, model, model year, and vehicle application) for which the claims hold. In the case of stationary and portable engines, applications can be relatively broadly defined (e.g. all constant speed applications). In the case of mobile engines, the applications may need to be more specifically defined.

If the manufacturer is claiming a percent emission reduction, the engine with the lowest applicable emissions in the engine family, or aggregate engine families, should be used for testing. If the manufacturer is claiming emission reductions to specified levels, the engine with the highest applicable emissions in the engine family, or aggregate engine families, should be used for testing. Note that verifying an emission control system to a specific emission level may have less applicability to other engine families than verifying to a specific emission reduction. For example, the verification of a particulate filter to an urban bus PM level of 0.01 g/bhp-hr is not likely to be applicable to refuse trucks, while verification to an 85 percent PM reduction level would be more applicable.

Following successful verification of emission reductions on the initial engine family, a manufacturer may submit data showing that the emission control system would be effective on other engine families in which the relevant parameters (e.g., exhaust temperature, backpressure, engine displacement) are equivalent. The ARB may request additional data or testing to support this equivalency, or may require that the manufacturer undergo the complete verification procedure on the new engine families.

Engine pre-conditioning: The manufacturer may tune-up or rebuild the engine only prior to baseline testing. Any tests conducted subsequent to a tune-up or rebuild will be considered a baseline test.

Emission control system pre-conditioning: The emission control system should be operated for a break-in period of at least 125 hours.

Test fuel: The test fuel should meet the specifications in the California Code of Regulations (Subsections 2280 through 2283 of Title 13), with the exception of the sulfur content or other properties previously identified by the manufacturer and approved by the Executive Officer. Testing of transit buses for PM reduction should use low-sulfur diesel fuel with a sulfur content no greater than 15 ppm by weight.

The sulfur content of the test fuel should be no less than 66 percent of the stated maximum sulfur content. For example, if a manufacturer is verifying the emission control system to a maximum of 500 ppm sulfur diesel fuel, the test fuel should not be less than 330 ppm sulfur by weight (500 ppm x 66% = 330 ppm). However,

manufacturers may use a test fuel with a sulfur content greater than the stated maximum fuel sulfur content.

Test cycle: The test engine should be tested on a series of operating cycles as indicated in Table 1. Baseline tests (without the emission control system) should be performed for each cycle at least as many times as shown in Table 1.

On-road engines and vehicles: For on-road diesel-fueled vehicles, manufacturers must choose between engine testing and chassis testing. Engine testing may be used for verification of either an absolute engine emissions level or a percent emission reduction; however, chassis testing may be used only to verify a percent emission reduction. If the manufacturer intends to use the initial data as durability data per Section 3, the manufacturer must follow the same testing option throughout.

Engine tests must consist of at least one cold-start and three hot-starts of the Federal Test Procedure (FTP) heavy-duty transient cycle for engines used in on-road applications. Chassis tests must consist of at least one cold-start and three hot-start heavy-duty Urban Dynamometer Driving Schedule (UDDS) cycles (see Code of Federal Registration, Part 86, Subpart M) and three hot-start New York Bus Cycles (NYBC).

Off-road engines and equipment (including portable engines): For off-road diesel-fueled vehicles and equipment, manufacturers must follow the steady-state test cycle outlined in the ARB off-road regulations (see California Code of Regulations, Title 13, Sections 2400 to 2447). Note that those regulations have incorporated ISO 8178 testing procedures[2]. The manufacturer must conduct three hot-starts of the appropriate steady-state test cycle from the ARB off-road regulations for specific off-road engines or equipment.

Stationary engines: For stationary engines, the most appropriate off-road test cycle representing the operating condition of the applications submitted by the manufacturer should be utilized. In the future, ARB staff will develop specific test procedures for these engines. We anticipate these test procedures to be similar to those called-out for off-road engines.

[2] The ISO 8178 standard was designed for various off-road engine applications. The ISO 8178 is actually a collection of many steady-state test cycles (type C1, C2, D1, etc.). Each of these cycles represents a sequence of several steady-state modes with different weighting factors.

Table 1
Test cycles for emission reduction testing

Test Type	On-Road	Off-Road (including portable engines)	Stationary
Engine	Transient FTP (1 cold-start and 3 hot-starts)	Steady-state test cycle from ARB off-road regulations	Steady-state test cycle from ARB stationary regulations
Chassis	UDDS (1 cold-start and 3 hot-starts) and NYBC (3 hot-starts)	N/A.	N/A.

FTP = Federal Test Procedure
UDDS = Urban Dynamometer Driving Schedule
NYBC = New York Bus Cycle

Emissions Testing: For an emission control system that requires regeneration events, the test cycle should be repeated as many times as needed for at least one regeneration event to occur. The average of all valid test cycle repetitions between regeneration events would be used for emission control system verification, including a minimum of one regeneration.

Test results: Test results must include baseline and post-control emissions of total PM, non-methane hydrocarbons or total hydrocarbons (whichever is used for the relevant engine or vehicle certification), NOx, and carbon monoxide. Any expected brake specific emissions must not exceed current emission standards authorized by law. Additional emission tests on the same engine, or chassis, and the same emission control system will be required if the coefficient of variation from test results exceeds 10 percent.

Additional exhaust analysis: Should the ARB have reason to believe that there may be an increase in toxic air contaminants as a result of the emission control system installation, the manufacturer may be required to perform additional exhaust analyses. This may only include at a minimum analyses of PM, benzene, 1,3-butadiene, formaldehyde, and acetaldehyde. Many components of uncontrolled diesel exhaust are toxic air contaminants and the emission control system should not increase the associated toxic risk.

Quality Control Data: The manufacturer of the emission control system must provide quality control data establishing that the test equipment used meets the specifications and calibrations given in the test procedures. Such data should be provided as an attachment to the application.

Determination of Emission Reduction: The verification of emission control system emission claims from the ARB will be based on the average of all valid test results before and after the installation of the emission control system. The calculation is shown below in Table 2.

Table 2
Emission Reduction Calculation

Verification Type	Emission Reduction
Percent Reduction	$\{ \frac{\text{Average Emissions}_{\text{without ECS}} - \text{Average Emissions}_{\text{with ECS}}}{\text{Average Emissions}_{\text{without ECS}}} \}*100\%$
Absolute Emissions	$\text{Average Emissions}_{\text{with ECS}}$

3. Durability Demonstration

The manufacturer must demonstrate the system's emission durability through actual field or bench testing.

Engine selection: The worst-case engine for durability should be selected for durability testing. Note that the worst-case engine for durability may not be the same as the worst-case engine for emissions discussed in the previous section. For example, a demonstration of percentage reduction may require testing the engine family with the lowest emissions, whereas the emission durability demonstration may require data from the engine or application with the lowest exhaust temperature and/or highest emissions.

Manufacturers may request ARB approval to apply durability data to other engine families by showing that emission durability demonstration conditions are similar to or worse than those expected from any carry-across engine family.

Test procedure: The minimum durability testing periods are shown in Table 3. For each engine type and size, the durability test period is that which occurs first. For example, the durability testing for an on-road 300 horsepower engine should be 5 years or 150,000 miles (or equivalent time in hours), whichever occurs first. A manufacturer may request ARB approval to use an accelerated durability test plan which will demonstrate that the device's emission durability is at least as great as that identified in Table 3.

Table 3
Minimum Durability Testing Periods

Engine Type	Engine Size	Minimum Durability Testing Period	
		Years	Activity
On-Road	Light heavy-duty, generally 70 to 170 hp, Gross Vehicle Weight Rating (GVWR) normally less than 19,500 lbs.	5 years	60,000 miles (or equivalent time in hours)
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	5 years	100,000 miles (or equivalent time in hours)
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	5 years	150,000 miles (or equivalent time in hours)
Off-Road (including portable engines) and Stationary	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	3 years	1,600 hours
	At or above 25 hp and under 50 hp	4 years	2,600 hours
	At or above 50 hp	5 years	4,200 hours

The durability test consists of (1) extended periods of time in which the emission control system operates in the field or on a cycle proposed by the manufacturer as approved by the ARB, and (2) emission reduction testing as described in Table 4. Emission tests of the emission control system for on-road, off-road, stationary, and off-road portable engines are required at 0 percent, 33 percent, 67 percent, and 100 percent of the relevant minimum durability period. In other words, four sets of tests are required throughout the minimum durability period. Note that the requirements of the initial durability test are identical to the testing requirements described in Section 2 (e.g., emission control system preconditioning of at least 125 hours, and the number of baseline tests required).

Table 4
Emission tests required for durability demonstrations

Application	Test Type	Test 1 (0% of durability period)	Test 2 (33% of durability period)	Test 3 (67% of durability period)	Test 4 (100% of durability period)
On-Road	Engine	Transient FTP (1 cold and 3 hot-starts)			
	Chassis	UDDS (1 cold-start and 3 hot-starts) and NYBC (3 hot-starts)			
Off-Road and portable engines	Engine	Appropriate steady-state test cycle			
Stationary	Engine	Appropriate steady-state test cycle			

If the manufacturer has not yet sufficiently demonstrated the durability requirements or needs additional time to confirm the impacts of the warranty requirements, the manufacturer may choose to develop durability data using an experimental permit, which can be granted by the ARB.

Maintenance: Only scheduled maintenance may be conducted on the engine and emission control system during the durability demonstration. If normal maintenance includes a change of any component of the emission control system, the time (miles, years, or hours) between component change must be included with the results of the demonstration. Additionally, any components to be replaced must be included with the original emission control system or included free of charge to the customer at the maintenance intervals.

Performance requirements: During the emissions durability period, the emission control system must meet the following requirements:

- Emission reductions must not be less than the claimed emission reductions.
- Emissions from the engine or vehicle and the emission control system should not exceed the claimed emissions.
- The emission control system should not result in any damage to the engine.
- Maintenance of the emission control system/engine beyond that specified in the emission control system's manual will only be allowed with prior ARB approval.

Conditional Verification: A conditional verification may be granted for manufacturers upon completion of 33 percent of the durability testing period, if ARB is convinced the

engine and application characteristics for the emission control system is technically feasible. This would allow the emission control system to be ready for sale before full verification. Full verification would be contingent on completion of the durability testing and submission of test results. These results must be submitted within a year after receiving temporary verification if bench aging is used and within three years if field-testing is used. If, for any reasons, the emission control system fails any of the durability test requirements within the required period, the conditional verification will be cancelled immediately. In addition, the manufacturer will be liable for replacing all emission control systems sold under the conditional verification when (1) the original emission control system reaches 33 percent of the minimum durability period and (2) when the replacement reaches 33 percent of the minimum durability period. Thus, the a purchaser would be assured of effective control over the entire minimum durability period. In general, ARB will not consider any partial emission credit if the emission control system fails to meet the 85% PM reduction or 0.01 g/bhp-hr PM emission level, except as noted in Section 1.

4. System Compatibility

Additional information is required to verify that an emission control system is compatible with the engine and operating conditions, and to establish the emission control system's operating requirements. The manufacturer must provide information relating to the following areas.

Engine backpressure: Retrofitting a vehicle often involves the installation of emission control equipment to the exhaust system of the vehicle. In some cases, this may result in increase of backpressure, which could put excessive loads on the turbocharger and engine, and increase fuel consumption. The manufacturer should demonstrate that the resulting backpressure is within the engine manufacturer's specified limits, or will not result in any damage to the engine. If operation of the engine with the emission control system installed will result in a gradual build up of backpressure that will eventually exceed the engine's specified limits, information regarding the reduction of backpressure should be included. This information includes, but is not limited to, the existence of backpressure monitoring devices, thresholds and control logic that are integrated into the system to notify the operator that backpressure limits have been exceeded, and whether the control logic requires any changes from engine to engine and/or application to application.

Application compatibility: In order to establish that the emission control system is compatible with the selected applications, the manufacturer should indicate the ranges of physical conditions under which the emission control system operates, and the conditions that could cause a reduction in performance. Complementing this, the manufacturer should provide temperature profiles, average duty cycles, and any other relevant parameters from field-collected data of the intended application. Sufficient data should be taken from the worst case engine or vehicle and the worst case operation,

per application, to determine worst case operating conditions[3]. These data should be compared with operational requirements of the emission control system to ensure proper design.

5. In-Use Inspection and Testing Requirements

Verified emission control systems will be subject to in-use inspection and testing requirements to ensure proper functioning in actual use. The form of these requirements has not yet been determined.

6. Other requirements

Emissions Defects Warranty: The manufacturer must provide an emissions defects warranty with minimum coverage as shown in Table 5. For each engine type and size, the defects warranty period should be that which occurs first. For example, the defects warranty period for an on-road 300 horsepower engine should be 4 years or 100,000 miles, whichever occurs first.

Table 5
Minimum Defects Warranty Periods

Engine Type	Engine Size	Minimum Defects Warranty Period	
		Years	Activity
On-Road	Light heavy-duty, generally 70 to 170 hp, GVWR normally less than 19,500 lbs.	4 years	40,000 miles
	Medium heavy-duty, generally 170 to 250 hp, GVWR normally from 19,500 lbs. to 33,000 lbs.	4 years	65,000 miles
	Heavy heavy-duty, generally exceeds 250 hp, GVWR normally exceeds 33,000 lbs.	4 years	100,000 miles
Off-Road (includes portable engines) and Stationary	Under 25 hp, and for constant speed engines rated under 50 hp with rated speeds greater than or equal to 3,000 rpm	2 years	1,100 hours
	At or above 25 hp and under 50 hp	3 years	1,800 hours
	At or above 50 hp	4 years	2,800 hours

During the defects warranty period, the manufacturer will be liable for any defects in the emission control system caused as a result of normal operation.

[3] The “worst case” is determined by the requirements of the emission control system.

System Labeling: The manufacturer should provide a label on the emission control system, which identifies the manufacturer, model, and the month and year of manufacture. A scale drawing of a sample label should also be submitted.

Owner's Manual: In addition, the manufacturer must provide a copy of the ESC owner's manual that clearly specifies the following information.

- Warranty statement including the warranty period over which the manufacturer is liable for any defects
- Installation and maintenance requirements for the emission control system
- Fuel consumption penalty, if any
- Fuel limitations, if any (e.g., sulfur content)
- emission control system maintenance requirements
- Contact information for the manufacturer of replacement components, cleaning agents, and/or disposal sites.